Tree use, feeding activity and diet of koalas on St Bees Island, Queensland

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ABSTRACT

Koalas *Phascolarctos cinereus* on St Bees Island displayed two significantly different patterns of tree species utilisation. Utilisation by day was complex with 36.5% in *Eucalyptus tereticornis,* Forest red gum, and 63.5% in a suite of non-eucalypt species. By night, utilisation was 80% *E. tereticornis*. Analysis of cuticle fragments in faecal pellets revealed almost 100% of the diet was composed of *E. tereticornis*. Nocturnal tree species utilisation differed from day use and from species occurrence in the diet. Direct observations of koala over 24 hrs found that 78.5% of feeding occurred at night. It was concluded that (1) observations of tree species use by day provided no indication of the composition of the koala diet on St Bees Island, (2) although observations of tree use by night provided a better estimate of the diet there were significant differences – probably associated with the nocturnal life of the koalas, and (3) it seems likely that analysis of cuticle fragments within faecal pellets is the most effective technique for understanding koala diet. The reliance of the St Bees Island koala population on a single eucalypt species was demonstrated.

Key words: koala, *Phascolarctos cinereus*, diet, nocturnal activity, tree use

Introduction

Since 1993 research on koalas *Phascolarctos cinereus* in Queensland has identified a discrepancy between diurnal tree species utilisation and the number and relative abundance of species appearing in the koala's diet (U Nyo Tun 1993, Hasegawa 1995, Melzer 1995, Ellis *et al.* 2002). Pfeiffer *et al.* (2005) found that St Bees Island koalas used different tree species assemblages by day and by night. Matthews *et al.* (2007) identified a similar differentiation within a coastal New South Wales koala population assuming the night time tree use was associated with feeding. Pfeiffer *et al.* (2005) hypothesised that the utilisation of these assemblages was subject to a drive to seek shelter and rest by day and a drive to feed by night. Day tree use may also reflect a learned or innate adaptation to predation by some raptors (Phillips 1990, Melzer *et al.* 2003). However, Logan and Sanson (2002) proposed that nocturnal activity, including feeding, was primarily a strategy to avoid activity at times of greatest environmental stress.

This paper examines the link between the nocturnal tree species use and koala feeding behaviour by exploring (a) nocturnal tree species use, (b) the composition and relative abundance of species in the koala's diet and (c) the timing of feeding activity by St Bees Island koalas.

Methods

St Bees Island

St Bees Island is a continental island of about 3,000 ha some 25 km north east of Mackay (20° 55'S, 149° 26'E). The island experiences a humid, tropical climate with very wet summers and dry, warm winters. The island vegetation is a complex of grasslands, shrublands, eucalypt forests, rainforest, littoral casuarina woodlands and mangroves. Koalas were introduced to the island from the adjacent mainland in the early 1930's (Berk 1995) and now range widely across the island – traversing all vegetation types. Koala densities appear to be higher in low forests dominated by *E. tereticornis* and it is in this habitat type where most of our observational research is undertaken.

Tree use

Two hundred and twenty observations of tree use by 12 male and 13 female radio-collared koalas were made over a 12 day period in October 2005. This included thirty nine observations of night tree use by four male and five female koalas. All observations were made in the same region of the island – low eucalypt forest surrounding Homestead Bay (20° 55' 45.30"S, 149° 26' 03.38"E). Night observations of tree use were conducted at random times between 18.00 hrs and 06.00 hrs. Times were selected from a computer-generated random number table. The species of tree was recorded whenever a koala was radio located. The data were expressed as percent utilisation by species by day and by night.

Diet

Fifteen samples of koala faecal pellets were collected in October 2005 from seven male and eight female koalas. The collections were made in the area where observations of tree use were made. Fresh pellets (soft, moist and, at times, with a mucous layer) were collected in the morning from the ground beneath trees containing a single koala of known gender. A pellet was selected randomly from each sample and analysed separately. Diet was determined through analysis of cuticle fragments in the faeces. Cuticle fragments were prepared by acid digestion (O'Brien 1981) and identified with reference to a locally derived library

of cuticles of known tree species to account for regional variation in epidermal characteristics (Weyers and Meidner 1990). Each sample was systematically searched until at least 300 cuticle fragments were examined and classified to genera or species or considered indeterminate. Data were expressed as average percentage per species.

Feeding activity

Three female koalas were observed over 24 hrs in October 2006. The method generally followed that described by Melzer (1995). Each koala was observed continuously. Every five minutes the animal's activity was recorded and classified. After sunset, observations were made with the aid of a red filtered light. When a koala descended a tree and moved away, the animal was not pursued immediately. The animal was monitored utilising the gain meter on the radio receiver until constant signal strength between consecutive readings indicated the animal had stopped moving. The animal was then radio-located, and continuous observations resumed. Data were expressed as percentages per activity class.

Analyses

Comparisons of tree species use between sexes was examined using Spearman rank order correlation. Given the very few records of species other than *E. tereticornis* in the diet analyses, comparisons of tree species use and diet were undertaken using the Fisher exact test on a 2 x 2 contingency table of *E. tereticornis* and grouped "other species" frequency data.

Results

Tree use

Twenty two species were used by the St Bees Island koalas during this study. Twenty one species were used by day and seven species by night (Table 1). *E. tereticornis* was the most frequently used tree species by day and by night. Despite that, tree species utilisation by day was complex with 63.5 percent of use among a diverse suite of 21 species other than *E. tereticornis*. Conversely, by night the utilisation pattern was simpler and *E. tereticornis* was the most frequently utilised species (82%).

Differences between sexes in utilisation of trees by day

Fifty two observations of tree use by male koalas and 129 observations of tree use by female koalas were made by day. These observations included the use of 13 species and three observations from trees of indeterminate type by males. Females were encountered in 19 species and two observations from two trees of indeterminate identification (Table 1). In both sexes the most frequently used species was *E. tereticornis*. There was no difference in the utilisation of species by sex by day ($r_s = 0.556$, $p = 0.007$).

Differences between sexes in utilisation of trees by night

Fifteen observations of tree use by male koalas at night and 25 observations of tree use by female koalas by night

Table 1. Relative use of tree species by St Bees Island koalas.

Species	% day-use n=181	% night-use n=40	Female % day use n=129	Male % day use n=52	Female % night use n=25	Male % night use n=15
Eucalyptus tereticornis	36.46	80	32.56	46.14	76.00	86.67
Mallotus philippensis	12.71	2.5	13.18	11.54	4.00	0
Corymbia clarksonia	6.63	2.5	6.98	5.75	4.00	0
Diospyros geminata	5.53	5	6.98	1.92	4.00	6.67
Pouteria sericea	5.53	0	3.88	9.62	0	0
Cryptocarya triplinervis	5.53	0	6.98	1.92	0	0
Allocasuarina littoralis	3.87	5	4.65	1.92	8.00	0
Pleiogynium timorense	3.32	0	3.88	1.92	0	0
Paraserianthes toona	2.76	0	2.33	3.85	0	0
Unknown	2.76	0	1.55	5.77	0	0
Ficus spp.	2.76	0	3.10	1.92	0	0
Cupaniopsis anacardioides	2.76	0	3.88	0	0	0
Acronychia laevis	1.66	0	2.33	0	0	0
Maytenus disperma	1.66	0	0.78	3.85	0	0
Neolitsea brassii	1.66	0	1.55	1.92	0	0
Acacia spirorbis	1.66	0	2.33	0	0	0
Ficus opposita	0.55	0	0.78	0	0	0
Eucalyptus platyphylla	0.552	2.5	0.78	0	4.00	0
Neisosperma poweri	0.55	0	0	1.92	0	0
Millettia pinnata	0.55	0	0.78	0	0	0
Cryptocarya hypospodia	0.55	0	0.78	0	0	0
Timonius timon	0	2.5	0	0	0	6.67

were collected. Males were encountered in three species while females were encountered in six species (Table 1.). As with day use species utilisation, *E. tereticornis* was the most frequently used species by both sexes. Despite that, there was a difference in the utilisation of species by sex by night (r_s = 0.4072, p = 0.06).

Differences between day and night tree species utilisation

There was no significant difference between sex in day species use, so sex-specific data sets of day species use were combined (Table 1) and tested against nocturnal tree species use by each sex. There was no difference between tree utilisation by day and female species use by night (r_s = 0.539, p = 0.01). There was, however, a difference between nocturnal tree species use by males and day species use (r_s = 0.161, p = 0.474). Both male and female koalas used *E. tereticornis* at a much higher frequency by night than by day. While both also used a suite of other species by night, the suite used by females was more similar to the day use pattern than the male koala's nocturnal species use.

Diet

The majority of the diet was composed of *E. tereticornis* (Table 2).There was no significant difference in diet between sexes (Fisher exact p=0.0592) so data were combined for subsequent analyses.

Tree use and diet

There was a significant difference between day tree species utilisation and species occurrence in faecal pellets (Fisher exact p=0.0000) and between night tree species utilisation and diet (males: Fisher exact p=0.0082, females: Fisher exact p=0.0000). Despite this there was some similarity between nocturnal tree species use and the frequency of species in the diet. Tree species use by night included *E. tereticornis* and six other species. The species in the diet included *E. tereticornis* and five other species. However, the frequency of occurrence of *E. tereticornis* in the diet exceeded the observed frequency of utilisation by night. Tree clustering using Euclidean distance illustrates this similarity (Figure 1).

Feeding Activity

In total 65 observations of feeding activity were recorded from the three female koalas (Figure 2). Most feeding (78.5%) occurred between 18.00 hrs and 06.00 hrs while 21.5 percent occurred after dawn between 07.00 and 09.00 hrs.

Discussion

This study identified differences between day time tree species use, night time species use and composition of the diet of male and female koalas from St Bees Island. There were no differences between sexes in the utilisation

Table 2. Relative occurrence of species in faecal pellets from St Bees Island koalas. (na – not applicable)

Species	Female diet % n=3002	Male diet % n=2406	mean % diet koalas n=15 leaf fragments n=5457
Eucalyptus tereticornis	94.46	98.71	96.73
Mallotus philippensis	0	0	0
Corymbia clarksonia	0.04	0.37	0.21
Diospyros geminata	0	0	0
Pouteria sericea	0	0	0
Cryptocarya triplinervis	0	0	0
Allocasuarina littoralis	0	0	0
Pleiogynium timorense	0	0	0
Paraserianthes toona	0	0	0
Ficus spp.	0	0	0
Cupaniopsis anacardioides	0	0	0
Acronychia laevis	0	0	0
Maytenus disperma	0	0	0
Neolitsea brassii	0	0	0
Acacia spirorbis	0	0	0
Ficus opposita	0	0	0
Eucalyptus platyphylla	0.31	0	0.15
Neisosperma poweri	0	0	0
Millettia pinnata	0	0	0
Cryptocarya hypospodia	0	0	0
Timonius timon	0	0	0
Unknown 1	1.73	0.68	1.17
Unknown 2	3.4	0.25	1.72
Unknown 3	0.06	0	0.03

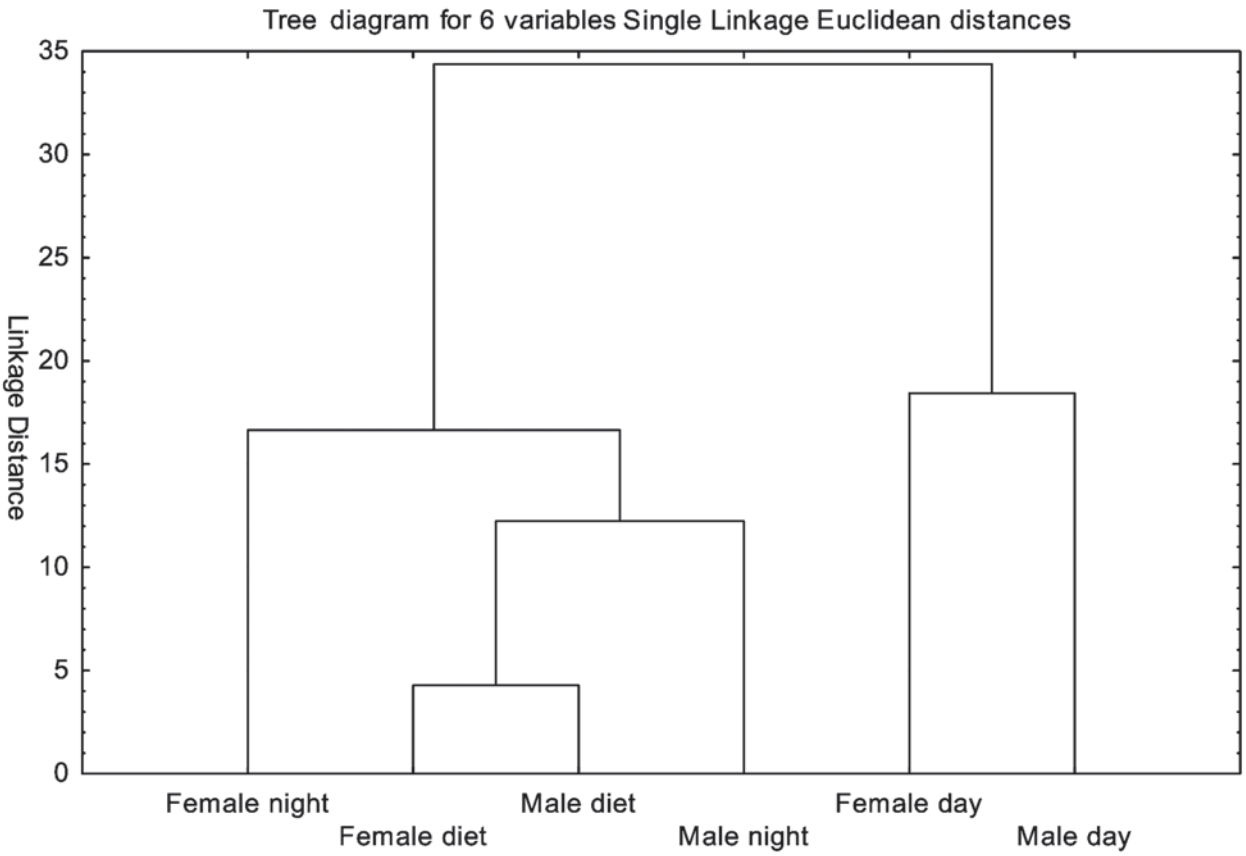

Figure 1. A tree diagram (a two dimensional representation) of the relationships among tree species use by St Bees Island koalas by day and by night as well as the species occurring in faecal pellets.

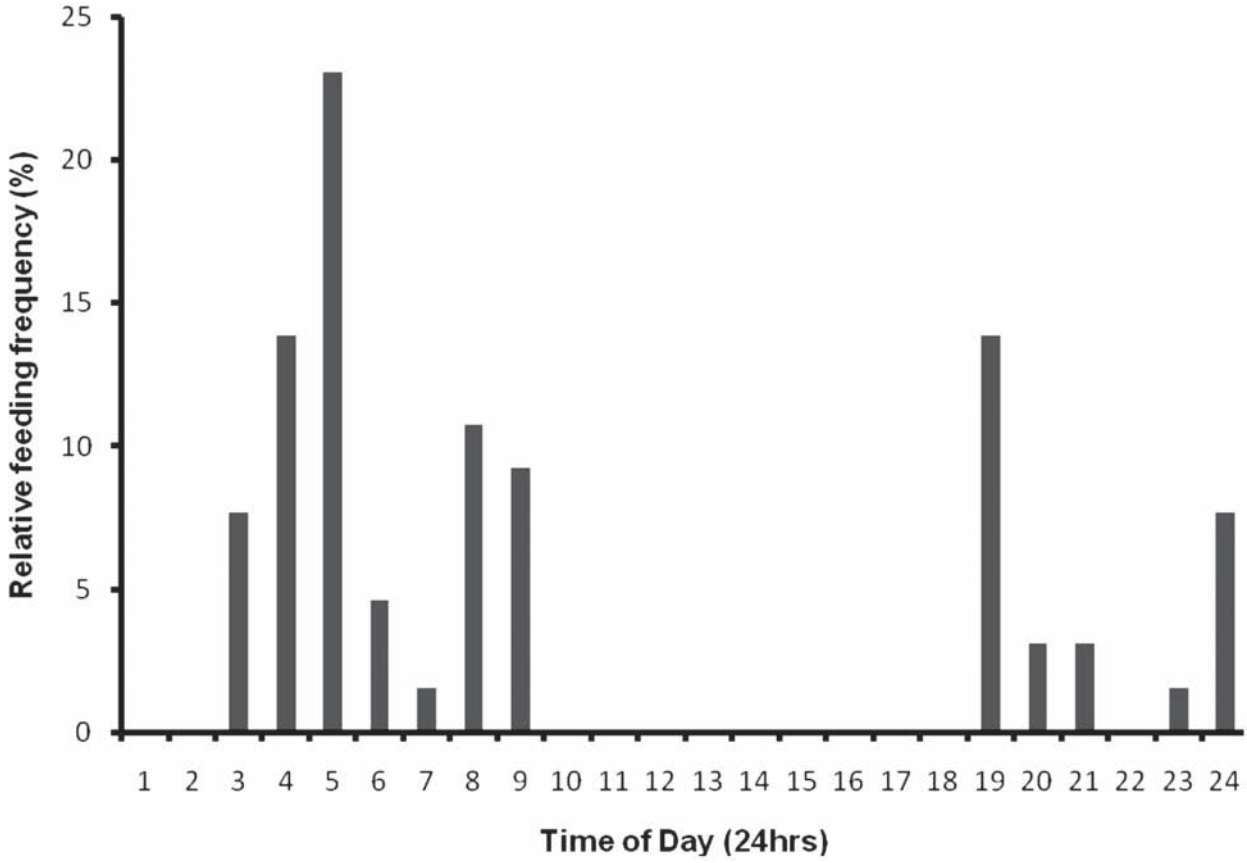

Figure 2. Timing (24 hrs) of feeding activity among three female St Bees Island koalas in October 2006.

of species by day and in the composition of the diet. However, there were differences between the sexes in the utilisation of species by night. Also, although there was a difference between the species used by male and female koalas by day and the species males use by night, this difference was not evident in the female koala species utilisation. So male and female koalas were using the same suite of species by day and the same suite of species for fodder. However, there was a difference in the suite of tree species each sex uses by night.

Pfeiffer *et al.* (2005) reported a difference between the day and night utilisation of tree species by a few St Bees Island koalas. This observation was subsequently confirmed on St Bees Island using a larger data set by Tucker *et al.* (2007) in relation to female and juvenile koalas. Further confirmation came from adult male and female koalas in a New South Wales population (Matthews *et al.* 2007) – although the authors only reported data from combined sexes. Here we also report a significant difference between tree species use by day and night in adult males. This difference was not apparent in the species utilisation by female koalas on St Bees Island, however – a result that contrasts with that reported by Tucker *et al.* (2007). These different results may reflect the different scale and extent of the two studies. Our study was undertaken in a single season (October 2005) and included females with and without offspring. The study of Tucker *et al.* (2007) focused on females with young and included data from four seasons over five years. However, we have already identified unexpected complexity in spatial dynamics among St Bees Island koalas (Ellis *et al.* 2009) and this result may be pointing to another aspect of this complexity.

Pfeiffer *et al.* (2005) hypothesised that the koalas utilised trees by day to reduce stress from heat and humidity. The hypothesis was based on direct day time observations of animal behaviour in exposed and sheltered positions. This hypothesis finds some recent support in Ellis *et al.* (2009) who measured a significant temperature differential between open and closed canopy trees. Such a benefit has long been proposed with larger trees or denser canopies presumed to provide shelter and, hence, aid in avoiding environmental stressors (*e.g.* Hindell and Lee, 1987, Martin and Handasyde 1999, Matthews *et al.* 2007, Ellis *et al.* 2009).

Pfeiffer *et al.* (2005) also hypothesised that tree utilisation by night on St Bees Island was associated with feeding activity – a view supported by Tucker *et al.* (2007). Neither study included any direct observations of feeding, however. Our results provide equivocal support Pfeiffer's hypothesis.

Feeding activity was predominantly nocturnal (78.5 percent between 18.00 hrs and 6.00 hrs) in the three animals studied here – and the utilisation of *E. tereticornis* by night was roughly double the day time utilisation. Although the number of observations of feeding is relatively low (n=65) the pattern of feeding is consistent with that identified among female koalas at Springsure in central Queensland (Melzer 1995). In that study of a sub-tropical, sub humid environment, 87.2 percent of female feeding occurred between 18.00 hrs and 6.00 hrs (n=3739). More observations on St Bees Island will better define the pattern of feeding in this warm, humid environment. This is also consistent with studies of *P. cinereus* in Victoria. The majority of feeding occurs at night – although some feeding could occur throughout the day (Hindell *et al.* 1985, Logan and Sanson 2002).

Matthews *et al.* (2007) did record feeding activity during the NSW study and, despite reporting significant differences between day and night tree species use, the majority of feeding events were reported during the day. Although they down-play these data and presume that most feeding actually occurs at night, it is possible that the population utilising the post-fire regrowth had modified its activity patterns to adapt to environmental or social stresses within the regrowth forest – in a manner analogous to that reported for koalas with advanced tooth wear by Logan and Sanson (2002).

On St Bees Island, although there was an increased use of *E. tereticornis* by night that can be attributed to observed feeding activity, there was a significant difference between the nocturnal tree species utilisation and the dietary composition. This should not be a surprise because koala activity is predominately nocturnal (e.g. Lee and Marin 1988, Melzer 1995, Logan and Sanson 2002) and includes interacting, moving between trees and dispersing as well as feeding. So our observations of nocturnal tree use may be related to a range of activities – some of which, perhaps most, include feeding.

Given the capacity for feeding to occur throughout the day, all-be-it at a reduced frequency, Logan and Sanson (2002) argue that the primary driver of nocturnal tree-use is to avoid day-time environmental stress by being most active by night and, conversely, being least active, adopting postural strategies to reduce heat and maximise shade (avoiding heat and humidity stressors) by day. Our results tend to be more consistent with this hypothesis than with the drive to feed proposed by Pfeiffer *et al.* (2005).

This study and others (Pfeiffer *et al.* 2005, Tucker *et al.* 2007) have revealed the extent to which this island koala population is dependent on *E. tereticornis*. It is the most frequently used tree species by day and night and constitutes over 90 percent of the diet. Consequently the koala population is vulnerable to island wide defoliation of *E. tereticornis* by fire, drought or insect attack, changes in foliage condition or to a general decline of this eucalypt species on the island. These risks may be likely. Intensification of dry seasons and drought conditions is expected as climate change scenarios evolve along with an increasing frequency of high fire risk days (*e.g.* Jones and Preston 2006). Recent drought-induced death of eucalypt and non-eucalypt species is evident across the island. Also we have identified a general failure of *E. tereticornis* to germinate on St Bees Island which, together with a tree size class distribution skewed to older individuals, indicates a gradual decline in *E. tereticornis* communities on the island (Melzer and Ellis 2009). Consequently, Queensland Parks and Wildlife Service has instigated a management program to address the threats to the *E. tereticornis* community and other island ecosystems (Melzer 2008). However, the vulnerability remains.

In conclusion, observations of tree species use by day provided no indication of the composition of the diet of the koala on St Bees Island and, although observations of tree use by night provided a better estimate of the diet, there were significant differences – probably associated with the nocturnal life of the koalas. It seems likely that analysis of cuticle fragments within faecal pellets is the most effective techniques for understanding koala diet. Consequently an understanding of tree species use by day and by night as well as pellet analyses are necessary to more fully comprehend the scope of habitat utilisation by the koala and the relative importance of habitat elements to the koala.

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